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DETERMINATION OF SOME STRUCTURAL FEATURES OF THE NEST PAPER OF *VESPA ORIENTALIS* LINNEAUS, 1771 AND *VESPA CRABRO* LINNEAUS, 1758 (HYMENOPTERA: VESPINAE) IN TURKEY

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Abstract – The aim of this study was to determine the nest materials and some physical features and elemental composition of *Vespa orientalis* and *Vespa crabro* nests. The nest surfaces were observed with a stereomicroscope and scanning electron microscope (SEM). In the *V. orientalis* nest, the average thickness of the fibers was 13.47μm, the nitrogen concentration was 18.75%, the percentages of the fibers, saliva, soil and the water absorption capacity were calculated to be 20%, 20%, 60% and 91%, respectively. In the *V. crabro* nest, the average thickness of the fibers was 11.48μm and the nitrogen concentration was 27.93%. The percentages of fiber, saliva and the water absorption capacity were calculated to be 23%, 77% and 100%, respectively.

Key words: *Vespa orientalis*, *Vespa crabro*, nest material, physical properties, SEM

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INTRODUCTION

Social wasps build their nests in dark places. Therefore, an envelope is constructed around the nest or the nest is built in a dark place (Spradbery, 1973; Edwards, 1980; Matsuura and Yamane, 1990). The species of Vespinae use paper pulps that are obtained from a mixture of oral secretions and plant fibers to build their nests (Evans and West Eberhard, 1970). They build their nests in nature by using various organic and inorganic materials (Spradbery, 1973; Edwards, 1980). The hornet (*Vespa*) gathers nest materials mostly from the xylem of rotten wood, the dead parts and bark of live trees. Mud and soil are used together with plant fibers as a building material. These building materials are masticated and mixed with saliva by the female hornets. The hornet's nest consists of a pedicel, a comb and an envelope (Spradbery, 1973; Edwards 1980; Ishay et al., 1986; Matsuura, 1991). The granules of organic and inorganic material contained in the Oriental hornet's comb are glued together by cement produced by the adults via their saliva. This cement protects the nest from rain and other weather conditions. The Oriental hornet fastidiously fastens each component of the comb wall (Ganor and Ishay, 1992). Some magnetic minerals such as Ti, Zr and Fe are embedded in the wall of the comb. The minerals in the hornet's comb can be found in the soil around the nest (Ishay et al., 2003, 2008). The nesting behavior of *V. crabro* is similar to that of *V. orientalis* (Matsuura 1991). Nesting data and some observations of *V. crabro* were reported by Archer (1980, 1984, 1985). The choice of nest site and plant fibers and the duration of chewing of nest materials by the hornet affect the physical features of the nest paper (Cole et al., 2001).

There are some faunistic studies about *V. crabro* and *V. orientalis* in Turkey. *V. crabro* is distributed in the north and *V. orientalis* in the other parts of Turkey (Kojima and Yıldırım 1991). However, the nesting behavior of the *Vespa* is little known. This is

the first study about the nesting behavior of *Vespa* in Turkey and it will be the base for future studies.

In this study, the paper of the nests of *Vespa orientalis* and *Vespa crabro* found in the field was analyzed in terms of its physical features. The surface of the nest was observed and the proportion of plant material and oral secretion, nest materials, fiber thickness, concentration of elements and the absorption capacity of the comb's wall were determined.

MATERIAL AND METHODS

Nest collection

The nest of *Vespa orientalis* Linnaeus, 1771 was collected in Nigde (34°37' E, 37°59' N, Turkey) on September 10, 2008. The nest of *Vespa crabro* Linnaeus, 1758 was collected in Zonguldak (31°39' E, 41°21' N, Turkey) on August 28, 2008. Larvae, pupae and eggs were removed from the nest. Small fragments were cut from the comb for observation. The nests were stored in the Entomology Laboratory at Biology Department of Nigde University, Turkey.

Observation of surface and analysis

Small fragments from nest's wall were observed with a stereomicroscope (OLYMPUS SZX16) and scanning electron microscope (LEO 440). The thickness of plant fibers were measured and elemental composition analysis was made by SEM (LEO 440). The edge length and diameter of the combs' cell were measured by stereomicroscope.

Percentage of plant material and oral secretion

The dried nest's fragment was weighed. A fragment of the wall was immersed in 0.5 N KOH solution and kept at 70°C for 4-5 h. The oral secretion was melted and fibers were unbound, the fibrous components were filtrated and separated from the secretion. The fibrous material was washed in water and dried in an electric oven. It was weighed with the filter paper. The percentage proportion of plant material and oral secretion were estimated using the following formula (Yamane et al., 1999):

Formula 1:

Fiber (Cellulose) (%) = $(k_1/ k_2) \times 100$
k_1= dried weight of sample before the process;
k_2 = dried weight of sample after the process.

Absorbance

Small fragments were weighed. Each fragment was reweighed after immersion in water for 30 s (Curtis et al., 2005). The absorption capacity, expressed as percentage, was estimated using the following formula:

Formula 2:

Absorption capacity (%) = $[(m_2-m_1)/ m_1] \times 100$
m_1= dried weight of sample before the process;
m_2 = dried weight of sample after 30 s.

RESULTS

The comb

There were no envelopes around the nests of *Vespa orientalis* and *Vespa crabro*. The *V. orientalis* nest consisted of a comb and a pedicel; the dry weight of the nest was 6.4846 g (n=1). The *V. crabro* nest consisted of three combs with four pedicels on the first comb, and the dry weight of the nest was 80.87 g (n=1). The measurements of the edge length and diameter of the combs' cell (mm) are shown in Table 1.

Table 1. The measurements of the edge length and diameter of the combs' cell (mm).

		V. orientalis	**V.crabro**
	n	10	30
Edge Length	Min.	5	4
	Max.	6	5
	Average	5.3±0.21	4.5±0.09
Diameter	Min.	8	8
	Max.	10	9
	Average	8.9±0.27	8.5±0.09

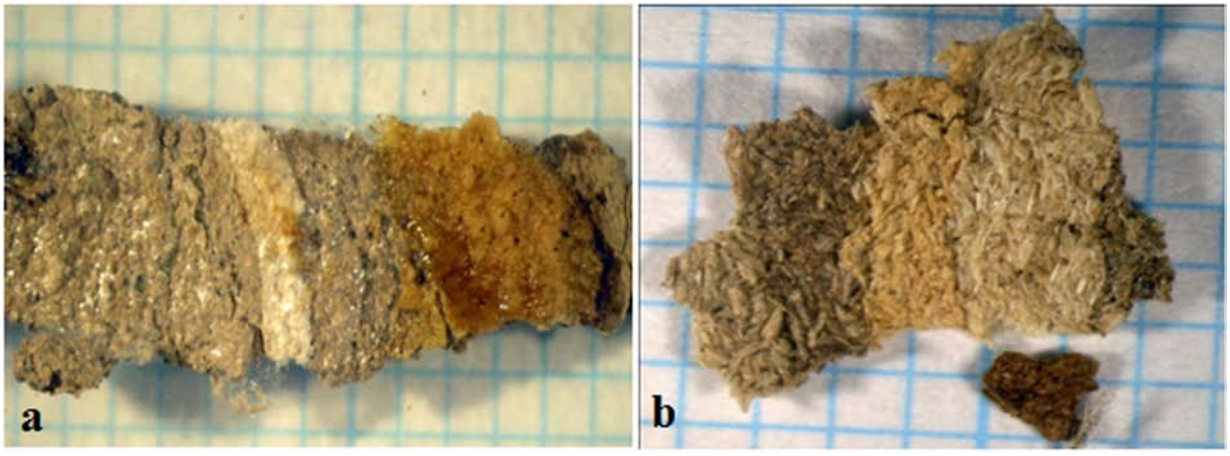

Fig. 1. Surface of nest's wall in stereomicroscope: a. *V. orientalis* (1x1), b. *V. crabro* (1x1,25).

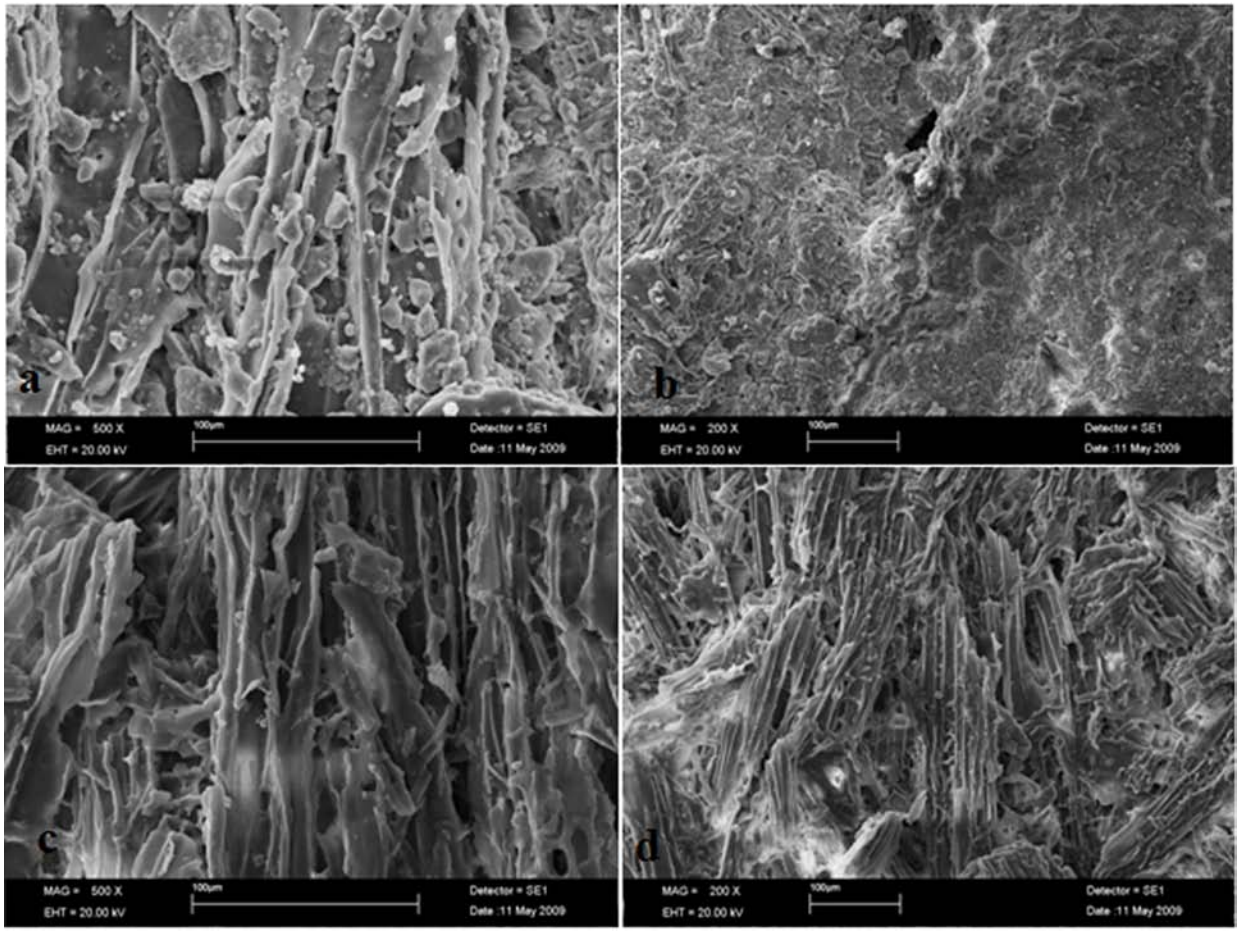

Fig. 2. Surface of the nest's wall in SEM, a-b: *V. orientalis,* c-d*: V. crabro.*

Observation of surface under light microscope

On the comb of *Vespa orientalis* L. there were beige, yellowish and brownish lines. The brown and yellow parts included soil. The beige part included fibers. The plant fibers were short and thick. The saliva shone like varnish (Fig. 1a). On the comb of *Vespa crabro* L there were also beige, yellowish and brownish lines. The plant fibers were short and thick. The fibers were glued closely. There were some inorganic materials between the fibers (Fig. 1b).

Observation of surface under SEM

Vespa orientalis L.: Two parts including fiber and soil were observed on the surface. The plant fibers were short and thick woody scrapings. There were inorganic materials, especially soil, between the fibers. There were no fibers in the soil (Fig. 2a-b). *Vespa crabro* L.: The plant fibers were short and thick woody scrapings. They were glued irregularly (Fig. 2c-d).

Thickness of the fiber

The thickness of the fiber is shown in Table 2.

Table 2. The thickness of the fiber (in micrometers).

		V. orientalis	**V. crabro**
	n	**10**	**10**
Thickness (μm)	Min.	7,41	6,31
	Max.	18,87	17,89
	Average	13.47±3.16	11.48±1.3

EDX Analysis

Vespa orientalis L.: oxygen, carbon, nitrogen, silicium, calcium, aluminum, potassium, iron, magnesium and sodium were determined in the fragment of the nest wall with EDX analysis. O, C and N were the major elements. Silicium was higher than the other inorganic elements. Silicium was in the state of silicium oxide. Silicium oxide is found in the sand. The soil of the nest was sand. The other inorganic elements were mixed in the sand. K, Mg, and Na were in very low concentrations. Fe was found as a magnetic mineral (Fig. 3). *Vespa crabro* L: O, C and N were the major elements. Si, Ca, Fe, K were in trace amounts. Al, Mg, Na were not found. The concentrations of elements are shown in Table 3. EDX spectra are shown in Fig. 3.

Table 3. Elements and their concentration in a fragment according to EDX analysis

Element	Concentration (%)	
	V. orientalis	V. crabro
O	43,47	38,13
C	24,15	32,53
N	18,75	27,93
Si	5,9	0,1
Ca	2,82	0,13
Al	2,07	-
Fe	1,47	0,42
K	0,75	0,75
Mg	0,41	-
Na	0,21	-

Percentages of plant material and oral secretion

The percentages of the fiber, saliva and soil in the *V. orientalis* nest were calculated to be 20%, 20% and 60%, respectively. The percentages of the fiber and saliva in the *V. crabro* nest were calculated as 23% and 77%, respectively.

Absorption capacity

The water absorption capacity of the nest fragments of *V. orientalis* and *V. crabro* were calculated as 91% and 100%, respectively.

DISCUSSION

Vespa orientalis prefer underground for their nests in Asia and hollow logs, attics and wall cavities in Europe and North America (Matsuura, 1991). In this study, the nest of *Vespa orientalis* was found in a wall cavity of an old building made from soil. The nest of *Vespa crabro* was found in the attic of a wooden house. Matsuura (1991) has reported that the structure of the envelope of a *Vespa* nest might be ball, bowl- or flask-shaped. The *Vespa* collects rotten wood, the dead parts of live trees and inorganic ma-

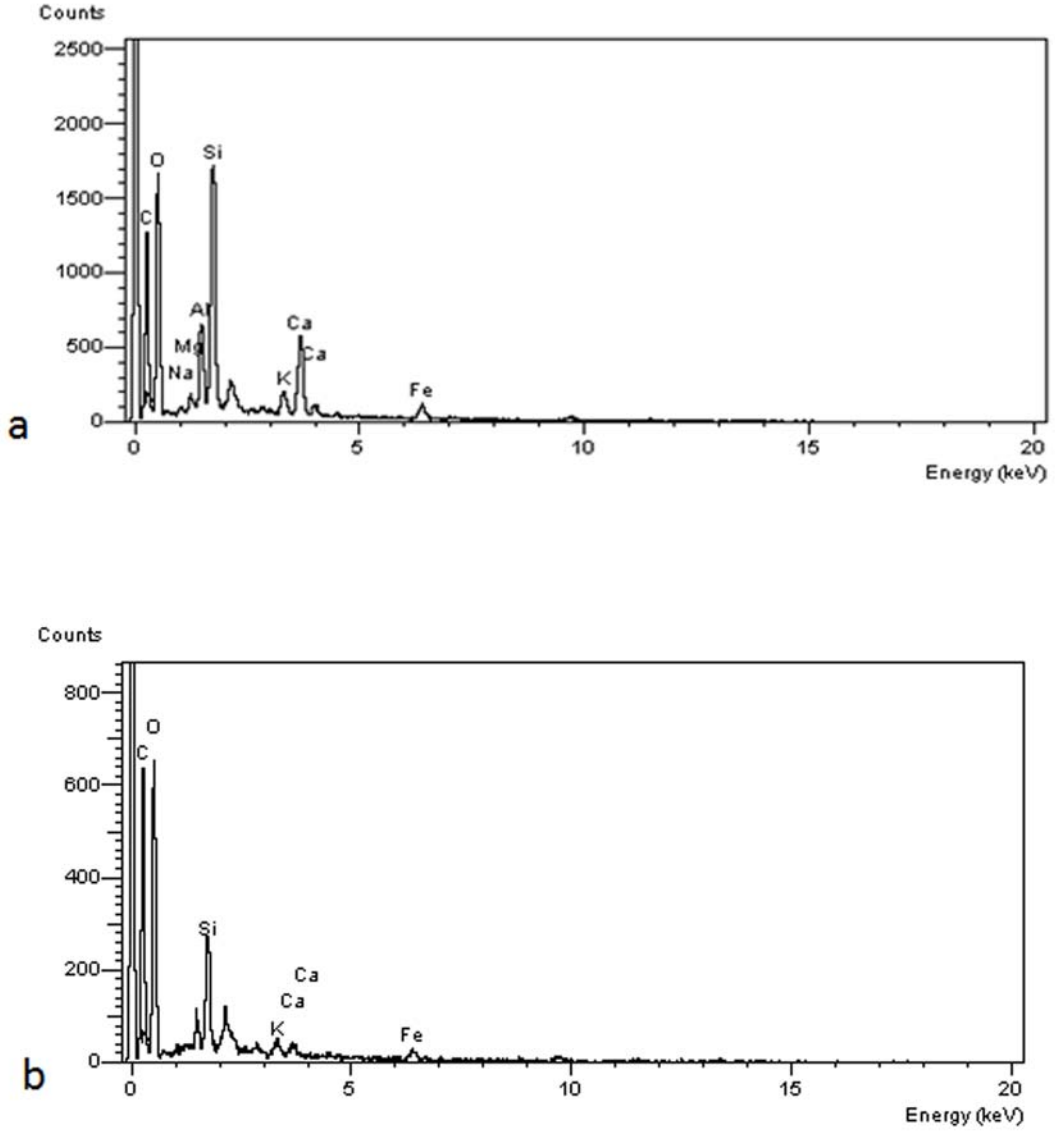

Fig. 3. EDX spectra of elements embedded in the wall of the comb: a. *V. orientalis*, b. *V. crabro*

terials as nest materials (Spradbery, 1973; Matsuura 1991). The nests which were found in this study had no envelopes around the combs. Short woody scrapings were found in the nests.

There were sand, red soil and garden soil as nest materials in the *Vespa orientalis* nest from Israel. The soil particles were composed mainly of Fe, Ti, Si and O with traces of Ca, K, Al and Mg according to the EDX spectra (Ishay et al., 2003, 2008). In this study, the concentration of O, C and N in the nests of each species were higher than the other elements. The soil in the nest of *V. orientalis* was sand. The sand was collected from the near surroundings of the nest by the hornet. There was a small amount of inorganic material in the nest fragment of *V. crabro*. The amount

of silicium in *V. orientalis* nest fragment was higher than that of the *V. crabro* nest fragment. The other elements were in trace amounts.

The nitrogen content of a fragment was analyzed because nitrogen can serve as an index of the amount of oral secretion. The nitrogen content of the nest of *Polybia paulista* was 1.59-2.14%. *Polybia paulista* uses a small amount of oral secretion for nest construction. The nitrogen content of the *Vespa analis* nest was 1.1-2.0%, *Vespa simillima* 0.9-2.0%, and *Vespa crabro* 2.5% (Kudô et al., 2001). The nitrogen concentration in the *V. orientalis* nest was 18.75%, *V. crabro* nest 27.93%. This nitrogen concentration is higher than that of the other species. The amount of oral secretion was equal to the amount of plant fibers, but the amount of soil was higher than the amount of oral secretion and plant fibers in the *V. orientalis* nest. The amount of saliva was higher than the amount of fiber in the *V. crabro* nest, because *V. crabro* used and glued only plant fibers as nest material.

Paper strength is highly dependent on its moisture content. There is a relationship between the water absorbency and low moisture content of the nest. The processing of pulp affects the sticking ability of the fibers, the absorbency of nest paper and its durability (Biermann, 1993). The saliva protects the nest from rain and other weather conditions (Kudô et al., 2001). The nest papers of *Dolichovespula sylvestris* and *Dolichovespula norwegica* were stronger, thinner and of higher quality than that of *Vespula vulgaris,* because the plant fibers preferred by *Vespula vulgaris* were short chips and woody scrapings (Cole et al., 2001). In this study, the nest wall of *Vespa orientalis* was very fragile. When it was touched, the nest chipped off. This is likely because the moisture content of the nest we analyzed was very low, and rotted woody fibers were preferred by hornets. The saliva was not effective on the water permeability of paper because the nest included dry fibers and sand which is hydrophilic. The water was absorbed by the dry soil and fibers. Thus, the water absorption capacity was considerably high. The absorption capacity of the nest wall of *V. crabro* was similar. The water was absorbed by fibers.

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